G-Series MFC
RS-485 Digital Interface

Supplement

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Chapter One: General Information

Introduction

This supplement provides instructions for operating MKS Mass Flow Devices (MFDs) using RS-485 digital communications. RS-485 digital operation is available with the MKS instruments listed in Table 0.

Mass Flow Devices with RS-485 Digital Communications	
Mass-Flo Controllers (MFCs)	**Mass-Flo Meters (MFMs)**
GE50A (elastomer sealed)	
GM50A (metal-sealed)	GM50A (metal sealed)
GV50A (elastomer sealed with integral shut-off vale)	

Table 1: Mass Flow Devices with RS-485 Digital Communications

The gas names, symbols, and code numbers for gases and vaporizable materials that may be used with mass flow devices, listed in Table C1, Appendix C, page 41, are from the SEMI® Standard E52, "*Practice for Referencing Gases used in Digital Mass Flow Controllers*." Your mass flow device stores information for near one hundred of these gases; however, only one gas can be active (monitored) at a time. The list of gases stored on the device may be viewed using the Setup Mode, Device Tab of the Ethernet User Interface.

Note  Use this document in conjunction with the instruction manual for your specific mass flow device.

Connectors

Note Overall metal braided shielded cables, properly grounded at both ends, are required during use to meet CE specifications.

RS-485 Digital Communications and Power Supply Connector (9 pin male D-sub)

The 9-pin male Type "D" interface connector, located on the top panel of the unit provides the RS485 digital communications and power input pins. These connections are also provided on the back panel of the device.

Caution **To prevent damage from electrostatic discharge (ESD) to the sensitive connector pins, they must be covered with an ESD protective cover when not in use.**

RS-485 Digital Communications and Power Supply Connector Pinouts	
Pin Number	**Assignment**
Pin 1	Power & Signal Common
Pin 2	+ 11 to 25 VDC Power In
Pin 3	No connection
Pin 4	No connection
Pin 5	B/B' (RS485+)
Pin 6	No connection
Pin 7	RS485 Common
Pin 8	Shield
Pin 9	A/A' (RS485-)

Table 2: Communications and Power Interface Connector Pinout

Note The "No Connection" pin assignment refers to a pin with no internal connection.

Ethernet User Interface (RJ45 Connector)

See the device user manual for use of the Ethernet User Interface.

Chapter Two: Communications

Device Initialization

When you apply power to the digital MFD, a series of steps occur as the unit is initializes. As each step occurs, the COMM LED on the top of the unit illuminates. The COMM LED sequence, which takes about ten (10) seconds, ***must*** be completed before any communication commands are issued.

At power up, after ten (10) seconds, the two (2) device LEDs will blink three (3) times and after which the yellow COMM LED will remain on.

Note  If the power up LED sequence stops before completion, the corresponding function has failed; contact MKS for assistance.

RS-485 Communication Parameters

The RS-485 interface supports 9,600, 19,200, and 38,400 baud. The RS-485 communication parameters listed in Table 1 are factory set and, except for the baud rate, cannot be adjusted.

RS-485 Communication Parameters	
Parameter	**Value**
Start Bit	1
Data Bits	8
Parity	no parity
Stop Bit	1
Baud Rate*	9,600 (initial); 19,200; 38,400
End-of-Line Delimiter	semicolon (;)
** User-adjustable*	

Table 3: RS-485 Communication Parameters

RS-485 Protocol

All RS-485 messages used by the mass flow device are composed of variable length ASCII strings. Messages sent to the unit from a remote computer are either *commands* that instruct the instrument to change an operating parameter, or *requests* that prompt the instrument to report information. Messages sent by the unit to a remote computer, are *responses*. Responses either acknowledge a command issued by the host computer, or reply to a request sent by the host computer.

Message Syntax

The RS-485 message syntax uses the following conventions:

Note

1. The series of up to three characters that identify the function must be entered in a command string in UPPERCASE text. If the command is entered incorrectly, the unit returns an *"Invalid Command"* error message (NAK 17).
2. The gas symbols used to identify the programmed gas calibration tables are ***case-sensitive*** and must be entered in the command string in the format listed in Table C1, Appendix C. The symbols are commonly accepted strings of ASCII characters with no subscripts, superscripts, or parentheses. If the gas symbol is not entered in the proper text format, an *"Invalid Gas"* error message (NAK 15) is returned.
3. Spaces and commas are included in the syntax for clarity only. Do not include spaces or commas in actual commands, unless specifically noted.

bold	Messages that you must enter exactly as shown in the manual. Do not include any spaces in the message string.
italics	Placeholder that represents text or numeric values that you must supply.
`response`	Format of message sent from the mass flow device.
;	Represents the end-of-line delimiter or termination character (specified in your communications software). All messages must use a semicolon (;) as the termination character.

Commands and Requests

Every message sent *from a remote computer* to the mass flow device must include the following information:

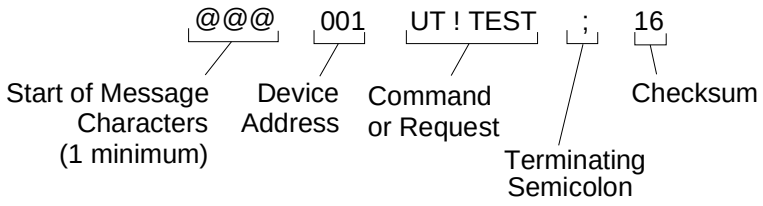

Figure 1: Example Command Message

Start of Message Character "@": At least 1 start of message character is required for the controller or meter to recognize that a message is being sent. Typically, 1 to 3 start of message characters are used.

Device Address: A 3 digit address (001, 002, and so forth, through 253) that identifies each individual unit.

Command/Request: A series of up to three characters that identify the function***. These characters must be entered in UPPERCASE text.*** The unit returns an *"Invalid Command"* error message (NAK 17) if the command is entered incorrectly.

The gas symbols used to identify the programmed gas calibration tables are ***case-sensitive*** and must be entered in the command string in the format listed in Table C1, Appendix C. The symbols are commonly accepted strings of ASCII characters with no subscripts, superscripts, or parentheses. If the gas symbol is not entered in the proper text format, an *"Invalid Gas"* error message (NAK 15) is returned.

Commands instruct the instrument to change an operating parameter. The command string is followed by an exclamation mark "!" and a data variable field (if relevant).

Requests prompt the instrument to report information. The command string is followed by a question mark "?" and a data variable field (if relevant).

Terminating Semicolon ";": Represents the end-of-line delimiter or termination character.

Command or Request Checksum: The sum of the ASCII values of the characters in the message from the *last* start of message character, up to and including the terminating semicolon, truncated to a hexadecimal integer (two characters). Refer to Figure 2, page 6, for an example of how the checksum is calculated.

How To Calculate the Command or Request Checksum

The checksum in a command or request message is calculated from the sum of the ASCII values of the characters in the message from the *last* start of message character "@", up to and including the terminating semicolon (refer to Figure 2), using a standard ASCII value chart (refer to Table B1, page 38).

The checksum is the decimal sum of the ASCII values, converted to a hexadecimal value and truncated to its last 2 characters.

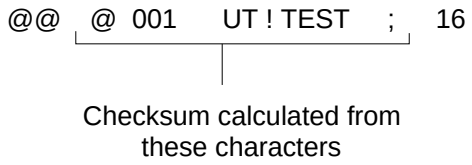

Figure 2: ASCII Characters in a Command Message Used to Calculate the Checksum

For example, the checksum value of "16" shown in Figure 2, was calculated as follows:

CHARACTER	ASCII CODE (decimal)
@	64
0	48
0	48
1	49
U	85
T	84
!	33
T	84
E	69
S	83
T	84
;	59
Sum =	790 (decimal)
=	316 (hexadecimal)

Checksum Value = 16*

* hexadecimal sum truncated to the last 2 characters

Note

1. You must include a checksum value with *every* command and request message sent to the mass flow device. The acceptable checksum values range from 00 to FF.
2. You can instruct the software to ignore the checksum by using the checksum value "FF" in *every* message.

How To Send a Command

A command message string consists of at least one start of message character "@", followed by the device address, a series of up to three characters "FNC" that identify the function, an exclamation mark "!" to identify the string as a command, a data variable field (if relevant), the terminating semicolon ";", and the checksum.

@@@001FNC!data variable;Checksum

How To Send a Request

A request message string consists of at least one start of message character "@", followed by the device address, a series of up to three characters "FNC" that identify the function, a question mark "?" to identify the string as a request, a data variable field (if relevant), the terminating semicolon ";", and the checksum.

@@@001FNC?data variable;Checksum

Responses

Every message sent *from the mass flow device* to a remote computer includes the following information:

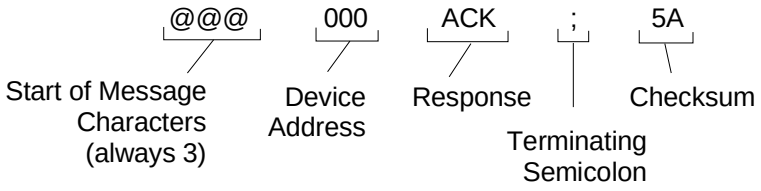

Figure 3: Example Response Message

Start of Message Character "@": Three (3) start of message characters are always sent from the mass flow device.

Device Address: The 3 digit address of the master device (always "000").

Response: A literal "ACK" (acknowledged) or "NAK" (not acknowledged) with a data variable field (if relevant). The response either acknowledges a command issued by the host computer, or replies to a request sent by the host computer.

Terminating Semicolon ";": Represents the end-of-line delimiter or termination character.

Response Checksum: The sum of the ASCII values of the characters in the message from the *first* start of message character, up to and including the terminating semicolon, truncated to a hexadecimal integer (two characters). Refer to Figure 4, page 9, for an example of how the checksum is calculated.

How To Interpret a Response

If a command or request is accepted and implemented, the response is the three start of message characters "@@@", followed by the address of the master device (always "000"), a literal "ACK" with a data variable field (if relevant), the terminating semicolon, and the checksum.

@@@000ACKdata variable;Checksum

If a command or request is either invalid or contained an error, the response is the three start of message characters "@@@", followed by the address of the master device (always "000"), a literal "NAK" with an error code, the terminating semicolon, and the checksum. The error codes are listed in Table 4.

@@@000NAKerrorcode;Checksum

RS-485 Error Codes	
Error Code	**Description**
01	Checksum error
10	Syntax error
11	Data length error
12	Invalid data
13	Invalid operating mode
14	Invalid action
15	Invalid gas
16	Invalid control mode
17	Invalid command
24	Calibration error
25	Flow too large
27	Too many gases in gas table
28	Flow cal error; valve not open
98	Internal device error
99	Internal device error

Table 4: RS-485 Error Codes

How the MFD Calculates the Response Checksum

The checksum in a response message is calculated from the sum of the ASCII values of the characters in the message from the *first* start of message character "@", up to and including the terminating semicolon (refer to Figure 0), using a standard ASCII value chart (refer to Table B1, page 38).

The checksum is the decimal sum of the ASCII values, converted to a hexadecimal value and truncated to its last 2 characters.

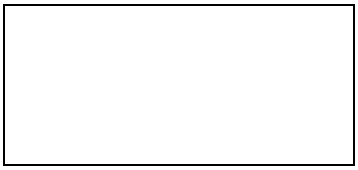

Figure 4: ASCII Characters in a Response Message Used to Calculate the Checksum

For example, the checksum value of "5A" shown Figure 0 was calculated as follows:

CHARACTER	ASCII CODE (decimal)
@	64
@	64
@	64
0	48
0	48
0	48
A	65
C	67
K	75
;	59
	Sum = 602 (decimal)
	= 25A (hexadecimal)

Checksum Value = 5A*

* hexadecimal sum truncated to the last 2 characters

Note If "FF" was used as the checksum in the command or request message (so that the software would ignore the checksum calculation), the mass flow device will respond by also using "FF" as the checksum.

Setup Messages

The Setup messages enable you to configure your mass flow device for operation, and allow you to review various factory set parameters.

Note

1. A device address of "254" and a checksum value of "FF" are used in the example messages shown in this section.
2. Commas are included in the syntax for clarity only. Do not include commas in actual commands, unless specifically noted.

RS-485 Setup Messages			
Command	**Description**	**Data Variables / Response**	**Mode(s)**
CC	Change Baud Rate	Enter 9600; 19200; 38400. Initial baud rate is 9600.	Run, Calibrate
CA	Change Address	Enter 001 to 253. Initial address is 254.	Run, Calibrate
UT	User Tag	Enter any user defined string of up to 30 ASCII characters. Spaces are valid characters.	Run, Calibrate
OM	Operating Mode	Enter RUN_MODE or CAL_MODE. Initial setting is RUN_MODE.	Run, Calibrate
GTS	Programmed Gas Table Size	Reports the total number of programmed gas tables stored in your unit (31 maximum).	Run, Calibrate *(query only)*
GL	Programmed Gas Table Search	Reports the gas symbol, gas code number, full scale range, and flow units for the gas table stored at the specified index location. Enter 0 to 31 to specify the gas table index location.	Calibrate *(query only)*
PG	Activate a Programmed Gas	Enter the gas symbol (refer to Table C1, Appendix C) for the gas to be monitored. Initial active programmed gas is nitrogen (N_2).	Calibrate

Table 5: RS-485 Setup Messages

(Continued on next page)

RS-485 Setup Messages *(Continued)*			
Command	**Description**	**Data Variables / Response**	**Mode(s)**
U	Flow Units	Reports the factory set units of sccm (standard cubic centimeters per minute) or slm (standard liters per minute).	Run, Calibrate *(query only)*
FS	Full Scale Range	Reports the factory set full scale range in flow units from 0.1 to 500000.0; 0.1 flow unit resolution.	Run, Calibrate *(query only)*
WK	Wink	Enter ON or OFF. Initial setting is OFF.	Run, Calibrate
RH	Run Hours Meter	Enter 0 to 65535 hours; 1 hour resolution.	Run, Calibrate *(query only)*

Table 5: RS-485 Setup Messages

How To Change the Baud Rate

This command sets the baud rate of the communications protocol. The baud rate changes *after* this command is complete and the response message is sent. The baud rate can be set to 9,600 (initial); 19,200; or 38,400.

Note

1. You must change the baud rate while the device is *off-line*, before it is connected to the network. If you try to change the baud rate after the device is on-line, and the network operates at a different baud rate than the one you commanded, communication cannot be established.
2. You must change the baud rate at both the instrument and the host computer.

To report the baud rate, enter:

@@@254CC?;FF

An example response is:

```
@@@000ACK9600;FF
```

To change the baud rate to 19,200, enter:

@@@254CC!19200;FF

How To Change the Address

This command changes the address of an individual device on the network. The address change takes effect *after* this command is complete and the response message is sent.

The address for an individual unit can range from 001 to 253; the initial address is 254. Addresses 254 and 255 are used for broadcasting messages to all devices on the network. All devices on the network will receive *and* respond to a command sent to address 254. All devices on the network will receive a command sent to address 255, but no device responds to it.

To query the current address, enter:

@@@254CA?;FF

An example response is:

`@@@000ACK254;FF`

To change the address from the initial setting of 254 to 001, enter:

@@@254CA!001;FF

Note

1. When you change the address from the initial setting of 254, the device must be *off-line*. If you change the address after the device is on-line, the network assumes the address change is for every device rather than for an individual device.
2. When an individual unit's address is between 1 and 253, the address can be changed with the device either on-line or off-line.

How To Enter a User Tag

A user tag is a label you assign to the mass flow device. The tag can be any user-defined string (including spaces) of up to 30 ASCII characters, and can be entered in either upper- or lowercase text.

To query the current user tag, enter:

@@@254UT?;FF

An example response is:

`@@@000ACKTEST;FF`

To enter a tag of "Process 1" send the command:

@@@254UT!PROCESS 1;FF

How To Set the Operating Mode

The operating mode places the mass flow device into one of its two modes: Run mode (initial power-up mode) or Calibrate mode.

To report the current operating mode, enter:

@@@254OM?;FF

An example response is:

@@@000ACKRUN_MODE;FF

To change to the Calibrate mode, enter:

@@@254OM!CAL_MODE;FF

How To Report the Number of Programmed Gas Tables

This query returns the *total* number of programmed gas tables, stored in your MFD. Your unit stores multiple gas tables, each containing information on a single gas (refer to Table C1, Appendix C, for more information). There is no command associated with this function.

To check the number of gases stored in your unit, enter:

@@@254GTS?;FF

An example response, if 10 gas tables are stored in your unit is:

@@@000ACK10;FF

How To Report the Programmed Gas Table Index Number

A maximum of 31 programmed gas tables can be stored in your device. The location where each gas table is stored is identified by an index number from 0 to 31. *The index numbers are factory set and cannot be changed.*

To identify which programmed gas table is stored at each index location, send the "GL" command and an index number. The query is accepted in either the Run or Calibrate modes. There is no command associated with this function.

To report which gas table is stored at index 0, enter:

@@@254GL?0;FF

An example response, if the argon gas table is stored at index 0, is:

`@@@000ACKAr,4,500,SCCM;FF`

The response reports the gas symbol (Ar) and gas code number (4) as they are listed in Table C1, Appendix C, the full scale range (500), and flow units (sccm) – *separated by commas* – for the programmed gas table stored at the specified index location.

Note  The gas symbol is reported in the format listed in Table C1, Appendix C.

How To Activate a Programmed Gas

This function allows you to set your device to control for a particular gas by activating the information stored in one of the programmed gas tables. Only one gas can be active at a time; corrections for the specified gas are automatically applied to the flow rate.

Note 

You must be in the Calibrate mode to query the current programmed gas or to activate one of the gas tables. Refer to *How To Set the Operating Mode*, page 13.

To report which of the programmed gases stored in your unit is currently active, enter:

@@@254PG?;FF

An example response, if the programmed gas is nitrogen, is:

@@@000ACKN2;FF

The response reports the gas symbol for the active programmed gas.

To change the active programmed gas, enter the "PG" command followed by the gas symbol for the gas of interest. For example, to program your device to monitor for argon (Ar), enter:

@@@254PG!Ar;FF

If you enter the gas symbol for a gas that is not stored in your device, or in an incorrect format, an *"Invalid Gas"* error message (NAK 15) will be returned.

Note 

1. The gas symbols are ***case-sensitive*** and must be entered in the command string in the format listed in Table C1, Appendix C. If the gas symbol is not entered in the proper text format, an *"Invalid Gas"* error message (NAK 15) is returned.
2. The "GL" query, used to report which gas is stored at each index location, reports the gas symbols in the correct format (refer to *How To Report the Programmed Gas Table Index Number*, page 14, for more information)

How To Report the Flow Units

This query returns the factory set flow units for the full scale range of the programmed gas. The units are either standard cubic centimeter per minute (sccm) or standard liters per minute (slm). There is no command associated with this function.

To report the flow units, enter:

@@@254U?;FF

An example response is:

@@@000ACKSCCM;FF

How To Report the Full Scale Range

This query reports the factory set full scale range, in flow units, for the programmed gas. There is no command associated with this function.

To report the full scale range, enter:

@@@254FS?;FF

An example response, if the full scale range is 200 sccm or 200 slm, is:

@@@000ACK200;FF

How To Use the Wink Command

This function controls the behavior of the visual indicator (wink function) on the device. This function controls the flashing of the Power LED, which is useful for visually identifying a particular device on the network.

When the wink function is ON, the Power LED on the top of the unit blinks once a second. When the wink function is OFF, the Power LED returns to its normal operation. The initial setting is OFF.

To query the present state of the wink function, enter:

@@@254WK?;FF

An example response is:

@@@000ACKOFF;FF

To turn the wink function ON, enter:

@@@254WK!ON;FF

How To Report the Run Hours

This function reports the total time the gauge has been ON in hours since the last time the run hours meter was reset. The resolution of the response is 1 hour. There is no command associated with this function.

To report the run hours, enter:

@@@254RH?;FF

An example response, if it has been four hours since the meter was reset, is:

@@@000ACK4;FF

Control Messages

The Control messages enable you to control the set point and valve operation in MFCs. If you are using a mass flow meter and issue these commands, an *"Invalid Command"* error message (NAK 17) will be returned. These messages can be sent from either the Run or Calibrate mode.

Note A device address of "254" and a checksum value of "FF" are used in the example messages shown in this section.

RS-485 Control Messages			
Command	**Description**	**Data Variables / Response**	**Mode**
CM	Control Mode	DIGITAL (Always)	Run, Calibrate
S	Set Point (% FS)	Enter a % of FS from -20.00% to +140.00%. Initial value is -20.00%.	Run, Calibrate
SX	Set Point (Units)	Enter a value from 0 to FS in flow units, either SCCM or SLM.	Run, Calibrate
FM	Freeze Mode	Enter FOLLOW or FREEZE. Initial setting is FOLLOW.	Run, Calibrate
SS	Softstart Rate	Enter a number of steps from 1 (fastest) to 200 (slowest). Initial setting is 1.	Run, Calibrate
VO*	Valve Override	Enter NORMAL, FLOW_OFF, or PURGE. Initial setting is NORMAL.	Run, Calibrate
VD*	Valve Drive Level	Reports the valve current as a % of FS from 0 to 100%.	Run, Calibrate *(query only)*

Table 6: RS-485 Control Messages

How To Set the Value of the Set Point

This function sets the set point value – the value to which the device is controlling the flow of gas. The set point can be set as a percentage of the full scale or in the flow units of the programmed gas. The two flow set point commands ("S" for % FS and "SX" for flow units) are linked. When one command is issued, the other is automatically updated. The last command entered takes priority.

For example, if the set point is set to 90% of full scale, and the full scale range is 200 sccm, the query for the set point in flow units will report 180 sccm.

How To Set the Set Point as a Percentage of Full Scale

This function allows you to set the set point as a percentage of the full scale of the programmed gas. The acceptable input range is -20.00% to 140.00%; the initial value is -20.00%.

To query the value of the set point as a percentage of full scale, enter:

@@@254S?;FF

An example response is:

```
@@@000ACK-20.000;FF
```

To change the set point to 100% of full scale, enter:

@@@254S!100;FF

How To Set the Set Point in Flow Units

This function allows you to set the set point in the flow units of the programmed gas. The acceptable input range is 0 to the full scale range of the programmed gas.

To query the value of the set point in the flow units of the programmed gas, enter:

@@@2541SX?;FF

An example response is:

```
@@@000ACK50.00;FF
```

To set the set point to 100 sccm, enter:

@@@254SX!100;FF

How To Set the Freeze/Follow Mode

This function defines the unit's *"freeze/follow"* mode. The *freeze* mode causes the unit to remain at the current set point. Any changes in the set point received while the unit is in the freeze mode are stored, but are not used. The *follow* mode (initial) releases the freeze mode, and causes the unit to move to the last specified set point.

To query whether the unit is in the freeze or follow mode, enter:

@@@254FM?;FF

An example response is:

`@@@000ACKFOLLOW;FF`

To change the unit to the freeze mode, enter:

@@@254FM!FREEZE;FF

The freeze/follow mode is most commonly used to synchronize multiple controllers. For example, ten MFC's could be commanded to freeze at their current set point, and then each one could be given a new set point. The new set points are not immediately used because the units are all in the Freeze mode.

Once all ten MFC's are set up, a FOLLOW command could be broadcast. Then, all of the MFC's would act on their new set points at the same instant. Note that to issue the broadcast FOLLOW command message, the address 255 should be used:

@@@255FM!FOLLOW;FF

All devices on the network will receive the message and act on it, but will not generate a response message.

How To Set the Softstart Rate

This function controls the rate at which flow moves toward the desired digital set point. The softstart rate defines how quickly the set point is ramped from its current value to the desired final value. The rate is expressed as a number of steps, ranging from 1 to 200; the initial setting is 1.

A softstart rate of 1 means that the set point will reach its final value in one step; *this is the fastest setting*. Each additional step adds 32 milliseconds to the set point response time. Therefore, a softstart rate of 50 means that on a set point change, the set point will ramp from its current value to the desired value in 50 steps, and will take approximately 1.6 seconds.

To query the softstart rate, enter:

@@@254SS?;FF

An example response is:

`@@@000ACK1;FF`

To set the softstart rate to 50, enter:

@@@254SS!50;FF

How To Set the Valve Override

This function is used to manually control the valve position in a mass flow controller. The valve can be set to normal (initial setting – valve is under set point control), flow off (valve closed), or purge (valve open).

To query the current valve position, enter:

@@@254VO?;FF

An example response is:

```
@@@000ACKNORMAL;FF
```

To change the valve position to purge, enter:

@@@254VO!PURGE;FF

How To Report the Valve Drive Level

This function monitors the control signal that causes the valve in the MFC to move. The valve may be closed at levels greater than zero and may be fully open at levels less than 100%. Use this query as a diagnostic tool to indicate the stability of the control circuit. The response returns the valve current as a percentage of full scale from 0 to 100%. There is no command associated with this function.

To report the valve drive level, enter:

@@@254VD?;FF

An example response, if the valve current is at 50% of full scale, is:

```
@@@000ACK50.0;FF
```

Flow Sensor Messages

The Flow Sensor messages enable you to control the variables used in the calculation of the indicated flow, to set up to four independent alarm levels, and to report the indicated flow rate.

Note A device address of "254" and a checksum value of "FF" are used in the example messages shown in this section.

RS-485 Flow Sensor Messages			
Command	**Description**	**Data Variables / Response**	**Mode**
AZ	Auto Zero	None; automatically zeros flow output.	Calibrate *(command only)*
H	High Trip Point	Enter a % of full scale from -140.00 to 140.00. Initial value is 100.00%.	Run, Calibrate
HH	High-High Trip Point	Enter a % of full scale from -140.00 to 140.00. Initial value is 100.00%.	Run, Calibrate
L	Low Trip Point	Enter a % of full scale from -140.00 to 140.00. Initial value is -100.00%.	Run, Calibrate
LL	Low-Low Trip Point	Enter a % of full scale from -140.00 to 140.00. Initial value is -100.00%.	Run, Calibrate
F	Indicated Flow Rate (% FS)	Reports the indicated flow as a % of full scale from -20.00% to +140.00%; 0.01% resolution. Initial value is 0.00%.	Run, Calibrate (*query only)*
FX	Indicated Flow Rate (Units)	Reports the indicated flow rate in units from 0 to full scale of the programmed gas.	Run, Calibrate (*query only)*
FT	Flow Totalizer	Reports the volume of gas in flow units that has passed through the unit since being reset. Initial value is 0.00. Enter any flow volume to reset.	Run, Calibrate

Table 7: RS-485 Flow Sensor Messages

How To Set the Auto Zero

This command automatically zeros the flow output of your mass flow device. The actual flow through the unit must be within 5% of zero. When there is no flow through the device, it should read zero. If it does not, send this command to automatically correct the flow reading.

There is no query associated with this command. The command is only accepted in the Calibrate mode.

To set the auto zero, enter:

@@@254AZ!;FF

How To Set the Trip Points

Trip points are used as high and low alarm levels for monitoring the set point error. The set point error is the difference between the actual gas flow and the set point. Two high level and two low level trip point alarm values can be set; the values are completely independent of each other. The action of the trip points is shown in Figure 5.

The trip point messages can be sent while the mass flow device is in either the Run or Calibrate mode.

Note The trip point status can only be reported by sending a status request query (refer to *How To Check the Instrument Status*, page 28); there are no visual indicators of the trip point status.

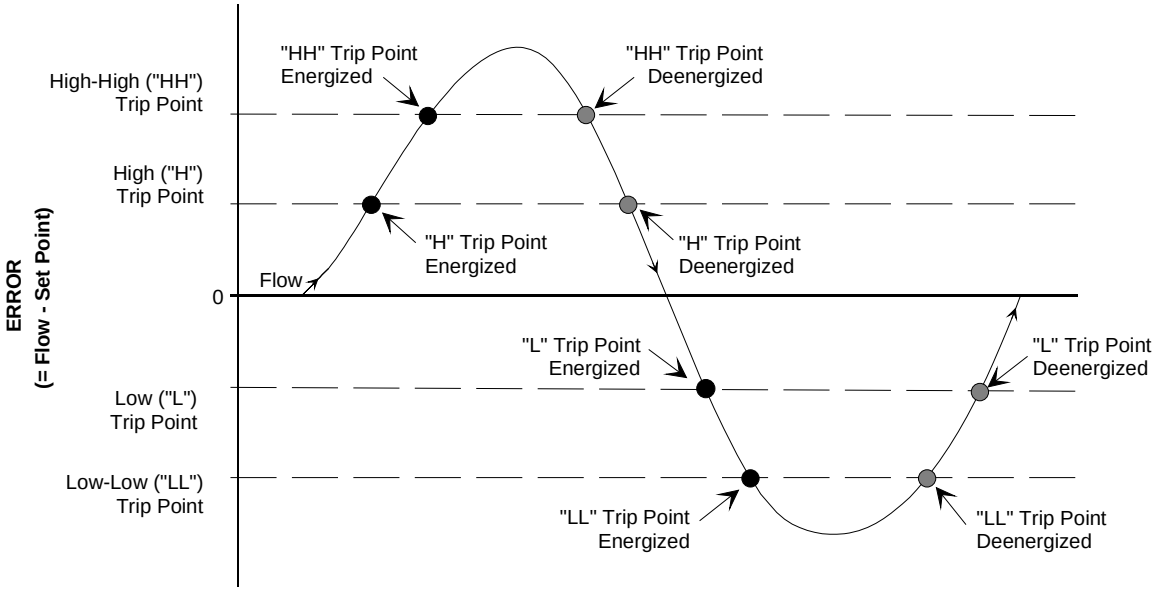

Figure 5: Trip Point Action

How To Set the High Trip Point

This function allows you to set or query the *high* level trip point as a percentage of full scale. The acceptable input range is -140.00% to 140.00%; the initial value is 100.00%.

To query the high trip point value, enter:

@@@254H?;FF

An example response is:

```
@@@000ACK100;FF
```

To change the high trip point value to 120% of full scale, enter:

@@@254H!120;FF

How To Set the High-High Trip Point

This function allows you to set or query the *high-high* level trip point as a percentage of full scale. The acceptable input range is -140.00% to 140.00%; the initial value is 100.00%.

To query the current high-high trip point value, enter:

@@@254HH?;FF

An example response is:

```
@@@000ACK100;FF
```

To change the high-high trip point value to 130% of full scale, enter:

@@@254HH!130;FF

How To Set the Low Trip Point

This function allows you to set or query the *low* level trip point as a percentage of full scale. The acceptable input range is -140.00% to 140.00%; the initial value is -100.00%.

To query the current low trip point value, enter:

@@@254L?;FF

An example response is:

```
@@@000ACK100;FF
```

To change the low trip point value to -120% of full scale, enter:

@@@254L!-120;FF

How To Set the Low-Low Trip Point

This function allows you to set or query the *low-low* level trip point as a percentage of full scale. The acceptable input range is -140.00% to 140.00%; the initial value is -100.00%.

To query the current low-low trip point value, enter:

@@@254LL?;FF

An example response is:

@@@000ACK100;FF

To change the low-low trip point value to -130% of full scale, enter:

@@@254LL!-130;FF

How To Report the Flow Rate

The indicated flow rate can be reported as a percentage of the full scale or in the flow units of the programmed gas. There are no commands associated with these functions.

How To Report the Flow Rate as a Percentage of Full Scale

The range of the response is -20.00% to 140.00% with a resolution of 0.01%; the initial value is 0.00%.

To report the flow as a percentage of full scale, enter:

@@@254F?;FF

An example response, with the flow at 90% of full scale is:

@@@000ACK90.00;FF

How To Report the Flow Rate in Units

The range of the response is 0 to full scale of the programmed gas; the initial value is 0.

To report the flow rate in units, enter:

@@@254FX?;FF

If the full scale range is 200 sccm and the flow is set to 90%, the response to this query is:

@@@000ACK180.00;FF

How To Use the Flow Totalizer

This function reports the volume of gas, in flow units, that has flowed through the unit since the last time the totalizer was reset.

To report the volume of gas measured by the flow totalizer, enter:

@@@254FT?;FF

An example response, if the flow is at 5000 sccm, is:

`@@@000ACK5000.0;FF`

The flow totalizer can be reset to zero or any other specified flow volume. To reset the flow totalizer to zero, enter:

@@@254FT!0;FF

Calibration Messages

RS-485 Calibration Messages			
Command	**Description**	**Data Variables / Response**	**Mode**
NGC	Number of Programmed Gas Calibration Points	Reports the number of data points in the *active* programmed gas calibration table; 15 maximum.	Run, Calibrate *(query only)*

Table 8: RS-485 Calibration Messages

Note

1. A device address of "254" and a checksum value of "FF" are used in the example messages shown in this section.
2. Spaces and commas are included in the syntax for clarity only. Do not include spaces or commas in actual commands, unless specifically noted.

How To Report the Number of Data Points in the Programmed Gas Table

The "NGC" query reports the number of data points (15 maximum) in the currently *active* programmed gas calibration table. The query is accepted in either the Run or Calibrate mode. There is no command associated with this function.

To report the number of points in the programmed gas calibration table, enter:

@@@254NGC?;FF

An example response, if there are 10 points in the calibration table, is:

`@@@000ACK10;FF`

Informational Messages

Informational messages report data on your mass flow device. These messages can be sent while the unit is in either the Run or Calibrate mode.

Note

1. A device address of "254" and a checksum value of "FF" are used in the example messages shown in this section.
2. Spaces and commas are included in the syntax for clarity only. Do not include spaces or commas in actual commands, unless specifically noted.

RS-485 Informational Messages			
Command	**Description**	**Data Variables / Response**	**Mode**
T	Status	*Reports:* C = Valve closed CR = Calibration recommended E = System error H = High alarm condition HH = High-high alarm condition IP = Insufficient gas inlet pressure L = Low alarm condition LL = Low-low alarm condition M = Memory (EEPROM) failure O = OK, no errors to report OC = Unexpected change in operating conditions P = Purge T = Over temperature U = Uncalibrated V = Valve drive level alarm condition	Run, Calibrate *(query only)*
SR	Status Reset	None; clears all status flags.	Run, Calibrate (*command only)*
GN	Gas Name or Number Search	Reports the gas name, code number, full scale range, and flow units for the specified gas.	Run, Calibrate *(query only)*

Table 9: RS-485 Informational Messages

(Continued on next page)

RS-485 Informational Messages *(Continued)*			
Function	**Description**	**Data Variable / Response**	**Mode**
SGN	Gas Code Number	Reports the gas code number for the active programmed gas.	Run, Calibrate *(query only)*
DT	Device Type	Reports the type of device; MFC or MFM.	Run, Calibrate *(query only)*
VT*	Valve Type	Reports the type of valve in a MFC; SOLENOID, VOICE_COIL, or PIEZO_ELECTRIC. Initial setting is SOLENOID.	Run, Calibrate *(query only)*
VPO*	Valve Power-Off State	Reports OPEN, CLOSED, or LAST_POSITION. Initial setting is CLOSED.	Run, Calibrate *(query only)*
MF	Manufacturer	Reports the maker of the device; MKS.	Run, Calibrate *(query only)*
MD	Model Designation	Reports the model number and revision levels for hardware and software.	Run, Calibrate *(query only)*
SN	Serial Number	Reports the serial number.	Run, Calibrate *(query only)*
TA	Internal Temperature	Reports the internal temperature of the device in degrees Celsius (° C).	Run, Calibrate *(query only)*
ST	Standard Temperature	Reports the standard calibration temperature in degrees Kelvin (° K). The response is always 273.0.	Run, Calibrate *(query only)*
SP	Standard Pressure	Reports the standard calibration pressure in kiloPascals (kPa). The response is always 101.1.	Run, Calibrate *(query only)*
** Valid for MFCs only.*			

Table 9: RS-485 Informational Messages

How To Check the Instrument Status

The status request reports on the state of the device. The response includes a string of characters *separated by commas*. Each character identifies a condition of the unit as listed in Table 9, page 26; every alarm condition is reported.

The query is accepted in either the Run or Calibrate mode. There is no command associated with this function.

To report the instrument status, enter:

@@@254T?;FF

If no error conditions exist, the response will be:

```
@@@000ACKO;FF
```

If a calibration is recommended and both high and high-high alarm conditions exists, the response will be:

```
@@@000ACKCR,H,HH;FF
```

How To Clear the Status Flags

The status reset command clears all status flags, described in Table 9, page 26. There is no query associated with this function.

To send a status reset command, enter:

@@@254SR!;FF

If an error occurs after the status flags are cleared, the flags are immediately reset.

How To Perform a Gas Name or Number Search

This query searches the stored programmed gas tables to see if they contain information on a specific gas. There is no command associated with this function.

A gas can be specified by its name (represented by its gas symbol) or code number. Refer to Table C1, Appendix C, for a complete listing of programmable gases, their corresponding gas symbols, and gas code numbers.

Note

1. The gas symbols are ***case-sensitive*** and must be entered in the command string in the format listed in Table C1, Appendix C. If the gas symbol is not entered in the proper text format, an *"Invalid Command"* error message (NAK 17) is returned.
2. The code number is an integer assigned by SEMI to identify a particular gas.

To search the tables for information on nitrogen using its gas symbol (N2), enter:

@@@254GN?N2;FF

To search the tables for information on nitrogen using its gas code number (13), enter:

@@@254GN?13;FF

An example response, for either query, is:

```
@@@000ACKN2,13,500.0,SCCM;FF
```

The response is the same regardless of whether the query asks the unit to search for the gas symbol or gas code number. In either case, the response includes the ***gas symbol, code number***, ***full scale range***, and ***flow units*** for the specified gas. The data reported is separated by commas.

If the gas does not exist in any of the factory set tables, an *"Invalid Gas"* error message (NAK 15) is returned. Refer to Table 4, page 8, for a complete list of error codes.

How To Report the Programmed Gas Code Number

This query reports the gas code number for the *active* programmed gas. There is no command associated with this function.

The gas code number is an integer assigned by SEMI to identify a particular gas. Refer to Table C1, Appendix C, for a complete listing of the programmable gases, their corresponding gas symbols, and gas code numbers.

To query the gas code number, enter:

@@@254SGN?;FF

An example response, if the programmed gas is nitrogen (gas code = 13), is:

```
@@@000ACK13;FF
```

How To Report the Device Type

This query reports the type of device being accessed. The unit is defined as either a mass flow controller (MFC) or mass flow meter (MFM). There is no command associated with this function.

To query the device type, enter:

@@@254DT?;FF

An example response is:

```
@@@000ACKMFC;FF
```

How To Report the Valve Type

This query reports the type of valve in the MFC; solenoid (initial), voice coil, or piezo electric. There is no command associated with this function.

To query the valve type, enter:

@@@254VT?;FF

An example response is:

```
@@@000ACKSOLENOID;FF
```

Note 

This query is only valid if you are using a mass flow controller. If you are using a mass flow meter and issue this query, an *"Invalid Command"* error message (NAK 17) will be returned.

How To Report the Valve Power-Off State

This query reports the normal, unpowered valve state for a mass flow controller as either open, closed (initial), or last position. There is no command associated with this function.

To check the valve state, enter:

@@@254VPO?;FF

An example response is:

```
@@@000ACKCLOSED;FF
```

Note This query is only valid if you are using a mass flow controller. If you are using a mass flow meter and issue this query, an *"Invalid Command"* error message (NAK 17) will be returned.

How To Report the Manufacturer

This query reports the maker of the mass flow device. The manufacturer of the unit is always reported as MKS Instruments, identified with the ASCII string "MKS." There is no command associated with this function.

To report the manufacturer, enter:

@@@254MF?;FF

The response will *always* be:

```
@@@000ACKMKS;FF
```

How To Report the Model Designation

This query returns information about the model number and revision levels for hardware and software. There is no command associated with this function.

To report the model designation, enter:

@@@254MD?;FF

An example response, if your unit is an 1179A MFC with Version 1.0 software, is:

```
@@@000ACK  1179A  V1.00;FF
```

Note Spaces are shown for clarity only; they are not present in the actual response.

How To Report the Serial Number

This query reports the unit's serial number. There is no command associated with this function.

To report the serial number, enter:

@@@254SN?;FF

An example response is:

```
@@@000ACK0123456789;FF
```

How To Report the Internal Temperature

This query reports the internal temperature of the device in degrees Celsius (° C). There is no command associated with this function.

To report the internal temperature, enter:

@@@254TA?;FF

An example response is:

```
@@@000ACK26.0;FF
```

How To Report the Standard Temperature

This query reports the standard temperature in degrees Kelvin (° K) at which your unit was calibrated for the active programmed gas. There is no command associated with this function.

To report the standard temperature, enter:

@@@254ST?;FF

The response will *always* be:

```
@@@000ACK273.0;FF
```

How To Report the Standard Pressure

This query returns the standard pressure, in kiloPascals (kPa), at which your unit was calibrated for the active programmed gas. There is no command associated with this function.

To report the standard pressure, enter:

@@@254SP?;FF

The response will *always* be:

```
@@@000ACK101.1;FF
```

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Appendix A: RS-485 Command Summary

The RS-485 command summary in Table A1 lists the Setup, Control, Flow Sensor, Calibration, and Informational commands for the mass flow device, *in the order they appear in the main text*. The table also includes information on when each parameter is saved, as well as its initial setting. For more information on each command, refer to Chapter Two: Communications, page 3.

RS-485 Command Summary						
		Settable in Mode				
Command	**Description**	**Run**	**Cal**	**Stored in EEPROM**	**When saved**	**Initial Setting**
CC	Change Baud Rate	Y	Y	Y	User changed	9600
CA	Change Address	Y	Y	Y	User changed	254
UT	User Tag	Y	Y	Y	User changed	None
OM	Operating Mode	Y	Y	N		RUN_MODE
GTS	Programmed Gas Table Size	N	N	Y		
GL	Programmed Gas Table Search	N	N	N		
PG	Activate a Programmed Gas	N	Y	Y	User changed	N2
U	Flow Units	N	N	Y	Factory Set ONLY	
FS	Full Scale Range	N	N	Y	Factory Set ONLY	
WK	Wink	Y	Y	N		OFF
RH	Run Hours Meter	N	N	Y		0

Table A1: RS-485 Command Summary
(Continued on next page)

RS-485 Command Summary *(Continued)*						
		Settable in Mode				
Command	**Description**	**Run**	**Cal**	**Stored in EEPROM**	**When saved**	**Initial Setting**
CM*	Control Mode	Y	Y	Y	User changed	ANALOG
S*	Set Pt (% FS)	Y	Y	N		-20.00
SX*	Set Pt (units)	Y	Y	N		
FM*	Freeze Mode	Y	Y	N		FOLLOW
SS*	Softstart Rate	Y	Y	Y	User changed	1
VO*	Valve Override	Y	Y	Y	User changed	NORMAL
VD*	Valve Drive Level	N	N	N		
AZ	Auto Zero	N	Y	N		
H	High Trip Point	Y	Y	Y	User changed	100.00
HH	High-High Trip Point	Y	Y	Y	User changed	100.00
L	Low Trip Point	Y	Y	Y	User changed	-100.00
LL	Low-Low Trip Point	Y	Y	Y	User changed	-100.00
F	Indicated Flow Rate (% FS)	N	N	N		0.00
FX	Indicated Flow Rate (Units)	N	N	N		0.00
FT	Flow Totalizer	Y	Y	N		0.0
NGC	Number of Programmed Gas Cal Pts	N	N	Y		

Table A1: RS-485 Command Summary

(Continued on next page)

RS-485 Command Summary *(Continued)*						
		Settable in Mode				
Command	**Description**	**Run**	**Cal**	**Stored in EEPROM**	**When saved**	**Initial Setting**
T	Status	N	N	N		O
SR	Status Reset	Y	Y	N		
GN	Gas Name or Number Search	N	N	N		
SGN	Gas Code Number	N	N	Y	Factory Set ONLY	
DT	Device Type	N	N	N	Hard Code	MFC/MFM
VT*	Valve Type	N	N	Y	Factory Set ONLY	
VPO*	Valve Power-Off State	N	N	Y	Factory Set ONLY	
MF	Manufacturer	N	N	N	Hard Code	MKS
MD	Model Designation	N	N	N	Hard Code	
SN	Serial Number	N	N	Y	Factory Set ONLY	
TA	Internal Temperature	N	N	N		
ST	Standard Temperature	N	N	N		273.00
SP	Standard Pressure	N	N	N		101.1

* *Valid for MFCs only.*

** *These parameters must be saved using the "SAV" command before leaving the Calibrate mode.*

*** *The "SAV" command must be issued before leaving the Calibrate mode in order to save any changes made to the highlighted (**) calibration table parameters.*

Table A1: RS-485 Command Summary

Appendix B: ASCII Value Chart

ASCII Value Chart					
Character	**ASCII Code (decimal)**	**Character**	**ASCII Code (decimal)**	**Character**	**ASCII Code (decimal)**
(sp)	32	3	51	F	70
!	33	4	52	G	71
"	34	5	53	H	72
#	35	6	54	I	73
$	36	7	55	J	74
%	37	8	56	K	75
&	38	9	57	L	76
'	39	:	58	M	77
(	40	;	59	N	78
)	41	<	60	O	79
*	42	=	61	P	80
+	43	>	62	Q	81
,	44	?	63	R	82
-	45	@	64	S	83
.	46	A	65	T	84
/	47	B	66	U	85
0	48	C	67	V	86
1	49	D	68	W	87
2	50	E	69	X	88

Table B1: ASCII Value Chart
(Continued on next page)

ASCII Value Chart *(Continued)*					
Character	**ASCII Code (decimal)**	**Character**	**ASCII Code (decimal)**	**Character**	**ASCII Code (decimal)**
Y	89	f	102	s	115
Z	90	g	103	t	116
[	91	h	104	u	117
\	92	i	105	v	118
]	93	j	106	w	119
^	94	k	107	x	120
_	95	l	108	y	121
`	96	m	109	z	122
a	97	n	110	{	123
b	98	o	111	|	124
c	99	p	112	}	125
d	100	q	113	~	126
e	101	r	114		127

Table B1: ASCII Value Chart

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Appendix C: Gas Table

Table C1 lists gas names, gas symbols, and code numbers for gases and vaporizable materials that may be used with mass flow devices. The gas names are listed alphabetically. The information in Table C1 is an excerpt from the SEMI® Standard E52, "*Practice for Referencing Gases used in Digital Mass Flow Controllers*."

The gas symbols, used to identify the programmed gas calibration tables, are ***case-sensitive*** and must be entered in the command string in the format listed in Table C1. The symbols are commonly accepted strings of ASCII characters with no subscripts, superscripts, or parentheses. If the gas symbol is not entered in the proper text format, an "*Invalid Gas*" error message (NAK 15) is returned.

Note 

The gas list provided here is for informational purposes only. For the list of gases stored on the MFC at time of shipment, please Consult MKS Applications.

Gas Table		
Gas Name	**Gas Symbol**	**Code Number**
2,2-Dichloro-1,1,1-Trifluoro-ethane	C2HCl2F3	186
4-Methyl-1-Pentene	C6H12	178
Acetone	C3H6O	184
Acetonitrile	C2H3N	173
Acetylene	C2H2	42
Air	Air	8
Allene	C3H4	66
Ammonia	NH3	29
Argon	Ar	4
Arsenic Pentafluoride	AsF5	96
Arsine	AsH3	35
Boron Tribromide	BBr3	79
Boron Trichloride	BCl3	70
Boron Trifluoride	BF3	48

Table C1: Gas Table

(Continued on next page)

Gas Table *(Continued)*		
Gas Name	**Gas Symbol**	**Code Number**
Bromine	Br2	21
Bromine Pentafluoride	BrF5	116
Bromine Trifluoride	BrF3	76
Bromotrifluoroethylene	C2BrF3	105
Bromotrifluoromethane	CBrF3	80
Butadiene	C4H6	100
Butane	C4H10	117
Butene	C4H8	104
Carbon Dioxide	CO2	25
Carbon Disulfide	CS2	40
Carbon Monoxide	CO	9
Carbon Tetrachloride	CCl4	101
Carbon Tetrafluoride	CF4	63
Carbonyl Fluoride	CF2O	46
Carbonyl Sulfide	COS	34
Chlorine	Cl2	19
Chlorine Trifluoride	ClF3	77
Chlorobenzene	C6H5Cl	172
Chlorodifluoromethane	CHClF2	57
Chloroform	CHCl3	71
Chloropentafluoroethane	C2ClF5	119
Chlorotrifluoromethane	CClF3	74
Cisbutene	C4H8	107
Cyanogen	C2N2	59
Cyanogen Chloride	ClCN	37
Cyclopropane	C3H6	61

Table C1: Gas Table

(Continued on next page)

Gas Table *(Continued)*		
Gas Name	**Gas Symbol**	**Code Number**
Deuterium	D2	14
Diborane	B2H6	58
Dibromotetrafluoroethane	C2Br2F4	130
Dichlorodifluoromethane	CCl2F2	84
Dichlorofluoromethane	CHCl2F	65
Dichlorosilane	SiH2Cl2	67
Dichlorotetrafluoroethane	C2Cl2F4	125
Diethysilane	C4H12Si	154
Difluorochloroethane	C2H3ClF2	103
Difluoroethane	C2H4F2	82
Difluoroethylene	C2H2F2	64
Difluorosilane	SiH2F2	134
Difluoromethane	CH2F2	160
Dimethyl Ether	C2H6O	73
Dimethylaluminumhydride	C2H7Al	164
Dimethylamine	C2H7N	85
Dimethylethylaminealane	C4H14NAl	166
Dimethylpropane	C5H12	122
Dimethylzinc	C2H6Zn	135
Disilane	Si2H6	97
Ethane	C2H6	54
Ethanol	C2H6O	136
Ethyl Acetylene	C4H6	93
Ethyl Chloride	C2H5Cl	75
Ethylbenzene	C8H10	174
Ethylene	C2H4	38

Table C1: Gas Table
(Continued on next page)

Gas Table *(Continued)*		
Gas Name	**Gas Symbol**	**Code Number**
Ethylene Oxide	C2H4O	45
Ethyleneglycol	C2H6O2	
Fluorine	F2	18
Fluoroform	CHF3	49
Germane	GeH4	43
Germanium Tetrachloride	GeCl4	113
Germanium Tetrafluoride	GeF4	99
Halothane	C2HBrClF3	137
Helium	He	1
Hexafluorethane	C2F6	118
Hexafluoropropylene	C3F6	138
Hexamethyldisilane	C6H18Si2	139
Hexane	C6H14	127
Hexanediol-1,6	C6H14O2	170
Hydrazine	N2H4	50
Hydrocyanic Acid	CHN	175
Hydrogen	H2	7
Hydrogen Bromide	HBr	10
Hydrogen Chloride	HCl	11
Hydrogen Cyanide	HCN	24
Hydrogen Fluoride	HF	12
Hydrogen Iodide	HI	17
Hydrogen Selenide	H2Se	23
Hydrogen Sulfide	H2S	22
Iodine Pentafluoride	IF5	115
Isobutane	C4H10	111
Isobutene	C4H8	106

Table C1: Gas Table
(Continued on next page)

Gas Table *(Continued)*		
Gas Name	**Gas Symbol**	**Code Number**
Krypton	Kr	5
Methane	CH4	28
Methanol	CH4O	176
Methyl Acetylene	C3H4	68
Methyl Bromide	CH3Br	44
Methyl Chloride	CH3Cl	36
Methyl Fluoride	CH3F	33
Methyl Mercaptan	CH4S	47
Methyl Vinyl Ether	C3H6O	81
Methylamine	CH5N	52
Methylbutene	C5H10	120
Methylcyclohexane	C7H14	177
Methylsilane	CH6Si	185
Methyltrichlorosilane	CH3Cl3Si	183
Molybdenum Hexafluoride	MoF6	124
Neon	Ne	2
Nickel Carbonyl	NiC4O4	140
Nitric Acid	HNO3	167
Nitric Oxide	NO	16
Nitrogen	N2	13
Nitrogen Dioxide	NO2	26
Nitrogen Tetroxide	N2O4	95
Nitrogen Trifluoride	NF3	53
Nitrogen Trioxide	N2O3	78
Nitrosyl Chloride	NOCl	141
Nitrous Oxide	N2O	27

Table C1: Gas Table

(Continued on next page)

Gas Table *(Continued)*		
Gas Name	**Gas Symbol**	**Code Number**
o-Xylene	C8H10	179
Octafluorocyclobutane	C4F8	129
Oxygen	O2	15
Oxygen Difluoride	OF2	41
Ozone	O3	30
Pentaborane	B5H9	142
Pentafluorethane	C2HF5	155
Perchloryl Fluoride	ClO3F	72
Perfluoropropane	C3F8	128
Phenol	C6H6O	180
Phosgene	CCl2O	60
Phosphine	PH3	31
Phosphorous Oxychloride	POCl3	102
Phosphorous Pentafluoride	PF5	143
Phosphorous Trifluoride	PF3	62
Propane	C3H8	89
Propylene	C3H6	69
Radon	Rn	3
Silane	SiH4	39
Silicon Tetrachloride	SiCl4	108
Silicon Tetrafluoride	SiF4	88
Sulfur Dioxide	SO2	32
Sulfur Hexafluoride	SF6	110
Sulfur Tetrafluoride	SF4	86
Sulfuric Acid	H2SO4	171
Sulfuryl Fluoride	SO2F2	87

Table C1: Gas Table

(Continued on next page)

Gas Table *(Continued)*		
Gas Name	**Gas Symbol**	**Code Number**
Tertiarybutylarsine	C4H11As	161
Tertiarybutylphosphine	C4H11P	162
Tetrachloroethylene	C2Cl4	168
Tetraethoxysilane	C8H20O4Si	144
Tetrafluorohydrazine	N2F4	157
Tetrafluoroethylene	C2F4	94
Tetrafluoroethane	C2H2F4	156
Tetrahydrofuran	C4H8O	182
Tetramethylcyclotetra-siloxane	C4H16Si4O4	158
Tin Tetrachloride	SnCl4	145
Titanium Tetrachloride	TiCl4	114
Toluene	C7H8	181
Transbutene	C4H8	98
Tribromomethane	CHBr3	83
Tributylaluminum	C12H27Al	146
Trichloroethane	C2H3Cl3	112
Trichlorofluoromethane	CCl3F	91
Trichlorosilane	SiHCl3	147
Trichlorotrifluoroethane	C2Cl3F3	126
Triethylborate	C6H15O3B	163
Triethylgallium	C6H15Ga	148
Trimethoxyborine	C3H9BO3	131
Trimethylaluminum	C3H9Al	149
Trimethylamine	C3H9N	109

Table C1: Gas Table

(Continued on next page)

Gas Table *(Continued)*		
Gas Name	**Gas Symbol**	**Code Number**
Trimethylamineallane	C3H12AlN	165
Trimethylantimony	C3H9Sb	150
Trimethylarsenic	C3H9As	151
Trimethylgallium	C3H9Ga	152
Trimethylindium	C3H9In	153
Trimethylphosphite	C3H9PO3	133
Trimethylphosphorous	C3H9P	132
Tritium	T2	159
Tungsten Hexafluoride	WF6	121
Uranium Hexafluoride	UF6	123
Vinyl Bromide	C2H3Br	56
Vinyl Chloride	C2H3Cl	55
Vinyl Fluoride	C2H3F	51
Water Vapor	H2O	20
Xenon	Xe	6

Table C1: Gas Table

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